

An Optical Survey for Space Debris on Highly Eccentric MEO Orbits

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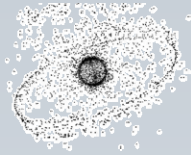
Space Debris Office, ESA/ESOC, Germany

62nd Deutscher Luft- und Raumfahrtkongress 2013,
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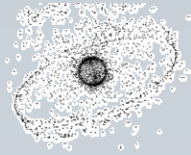
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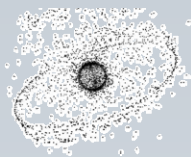
Outline

1. Introduction
2. Current TLE Population
3. Survey Strategies
4. Observations and Results
5. Conclusion



Main Objectives

- **Background:**
Fragmentation events (including deliberate events) in highly-eccentric MEO, in particular in Molniya-type orbits, are known.
- **Objectives:**
 - Develop observation strategies and make a comparative analyses
 - Demonstrate the feasibility and performance of the proposed observation strategies through an experimental observation campaign
 - Build-up and maintain a temporal catalogue

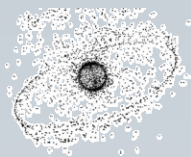


TLE Molniya Population

- Selection criteria
 - $60^\circ < i < 67^\circ$
 - $0.5 < e < 0.8$
 - $20000\text{km} < a < 30000\text{km}$

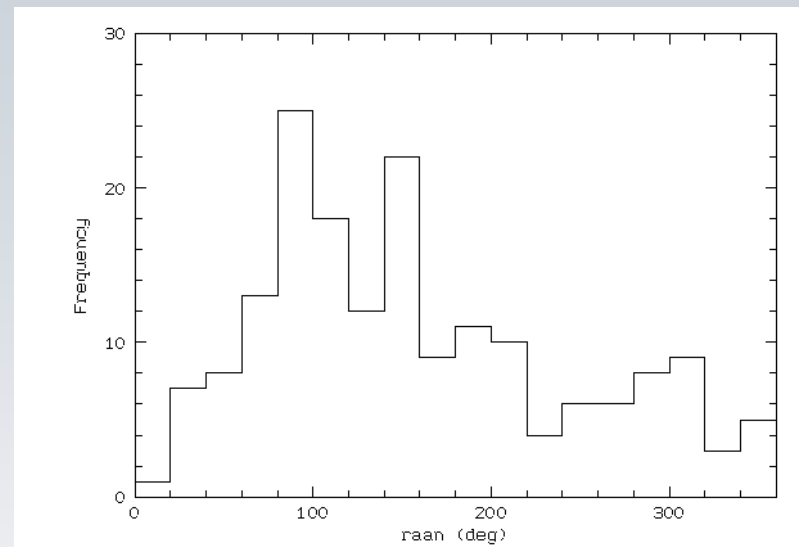
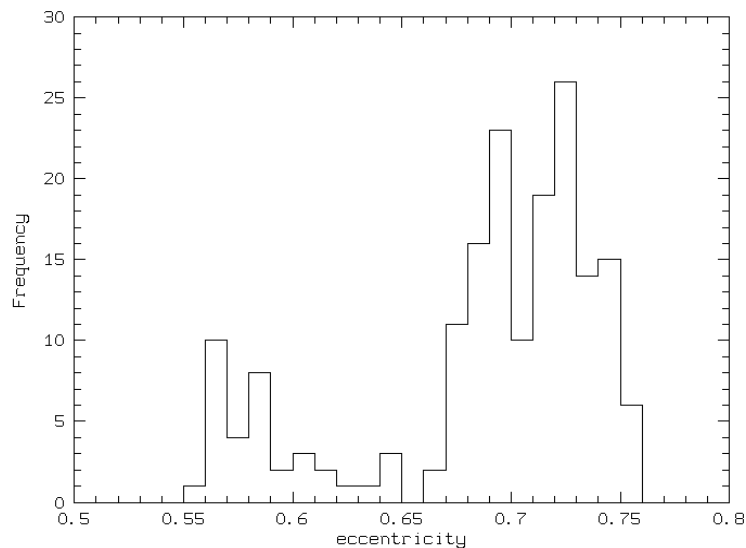
Objects	Quantity
MOLNIYA satellites	41
MERIDIAN satellites	4
Rocket bodies	73
Others	53
TOTAL	171

USSTRATCOM catalogue to January 2012

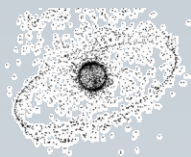


Current Population

- Node distributed over the whole range
- More objects between 80° and 160°

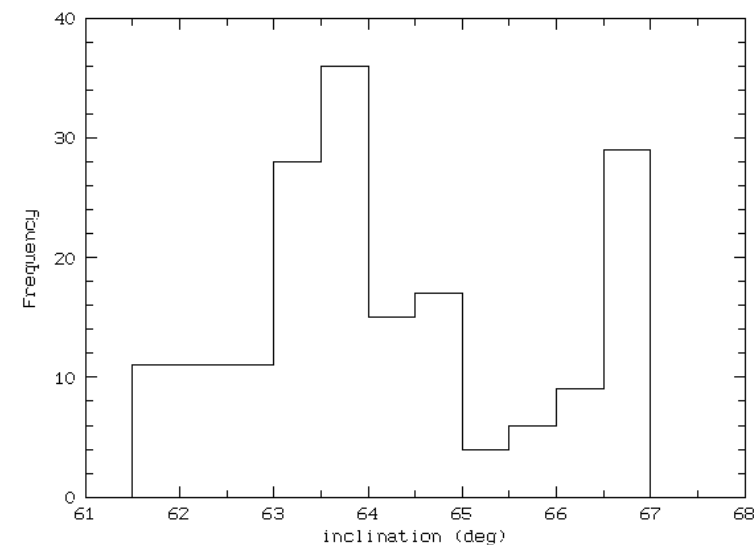
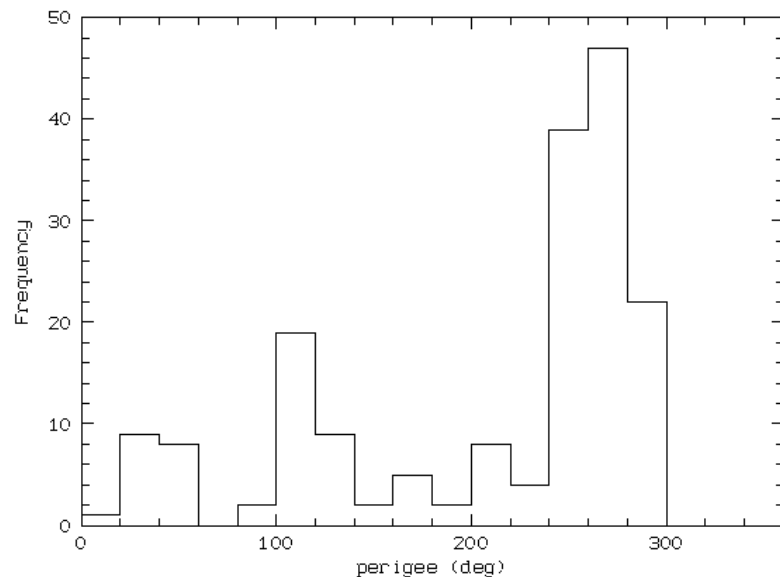


- 2 groups
- $e < 0.65$
 - Similar launch dates
 - perigee $< 180^\circ$

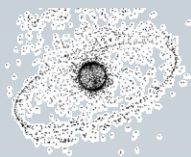


Current Population

- $i > 65 \rightarrow e < 0.65$
- Most objects distributed around 63.4 deg

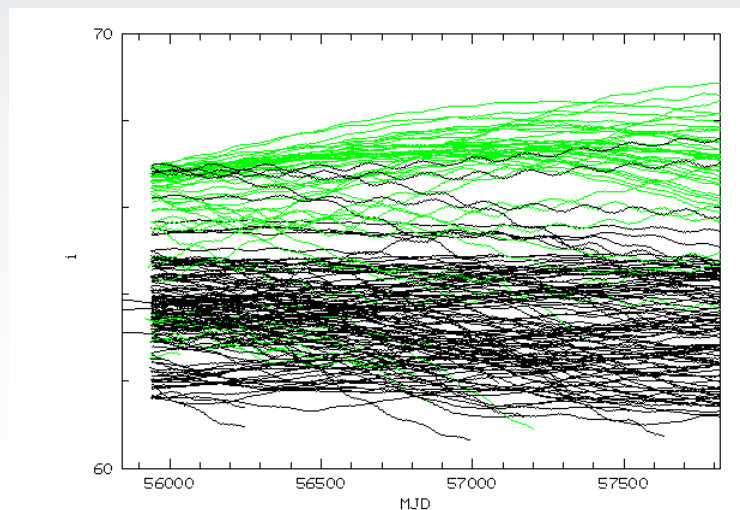
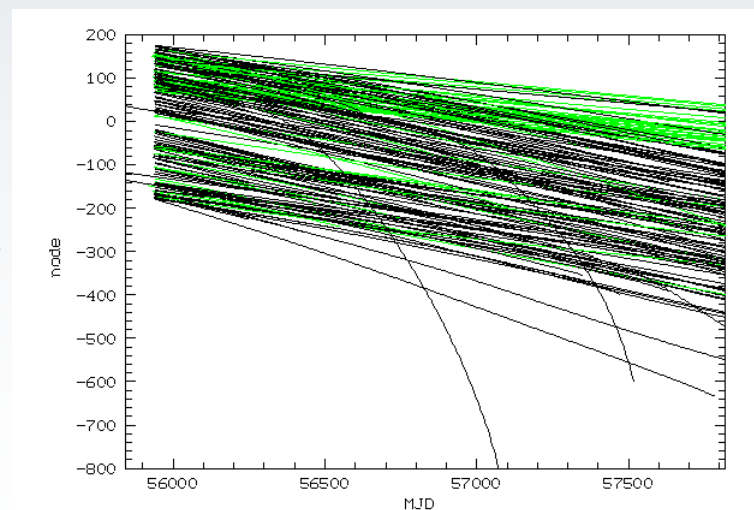
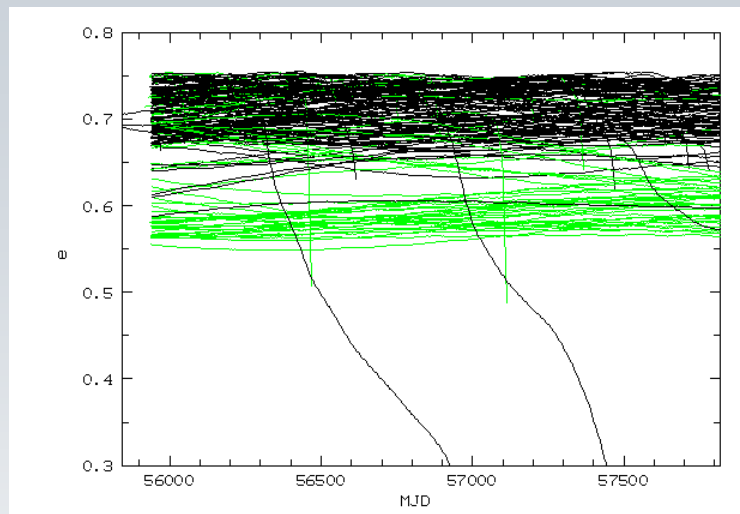


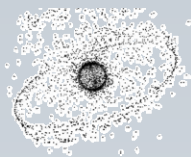
- Cover whole range
- Perigee for most of the objects around 270 deg



Evolution over 10 Years

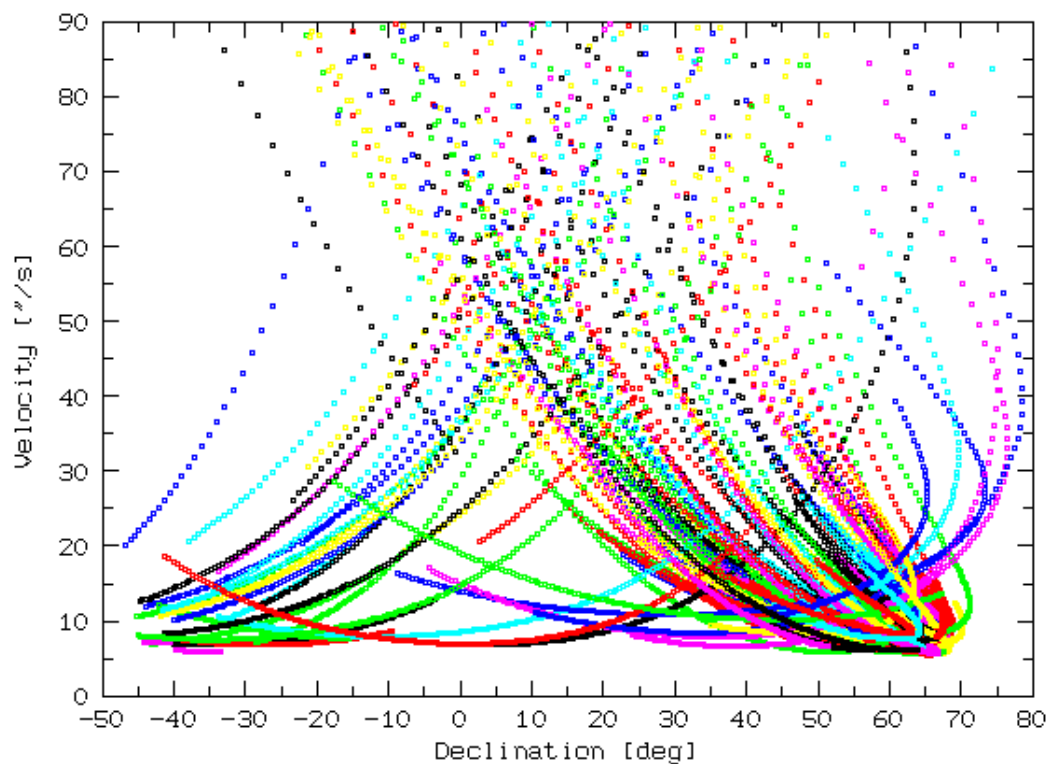
- Evolution over 20 years
- green: $e < 0.65$
- Similar distribution of orbital elements
- Node drift -0.1° to -0.2° per day $\rightarrow 36^\circ/\text{year}$

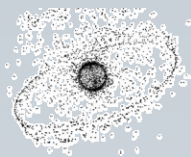




MEO Observation Strategies

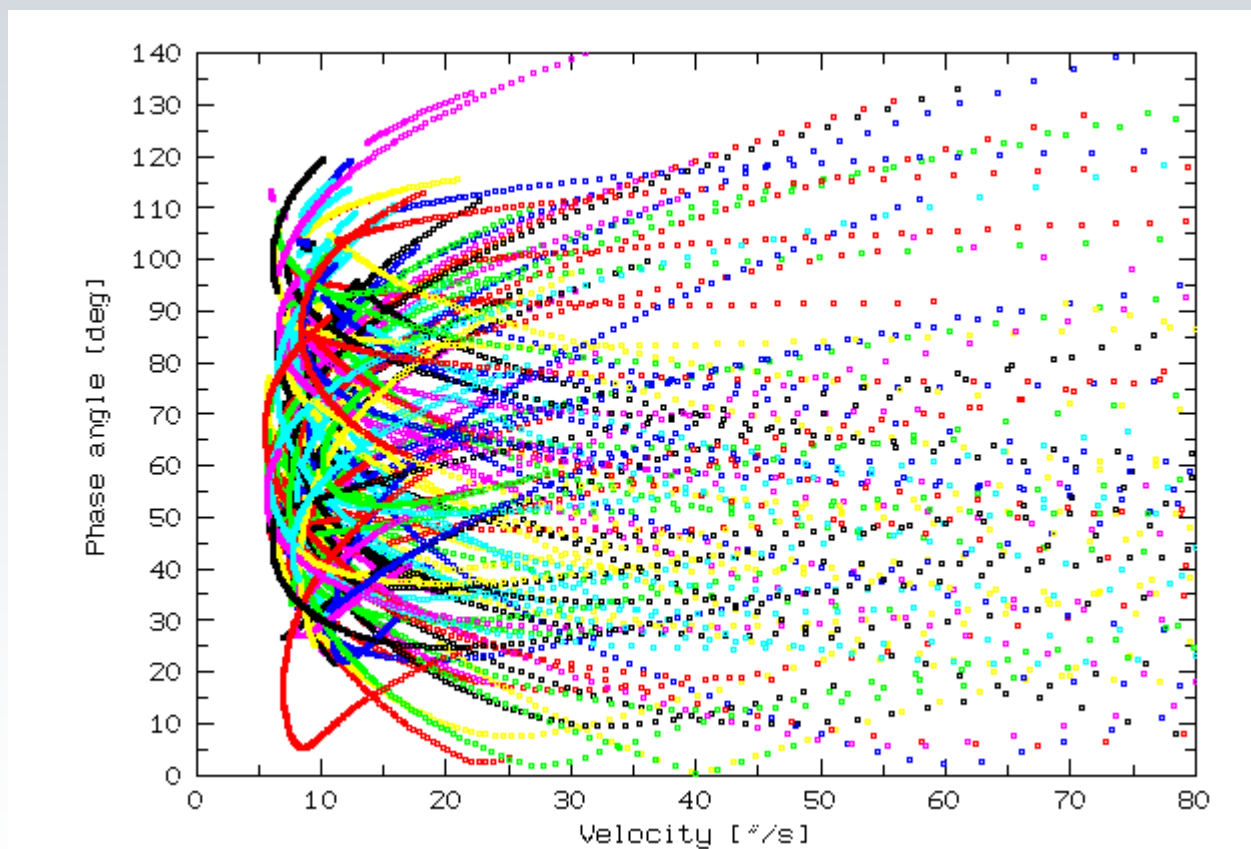
- Angular velocities (topocentric, OGS)
 - $V_{\min} = 5-10 \text{ arcs/s} \rightarrow \text{apogee}$

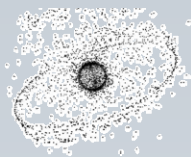




MEO Observation Strategies

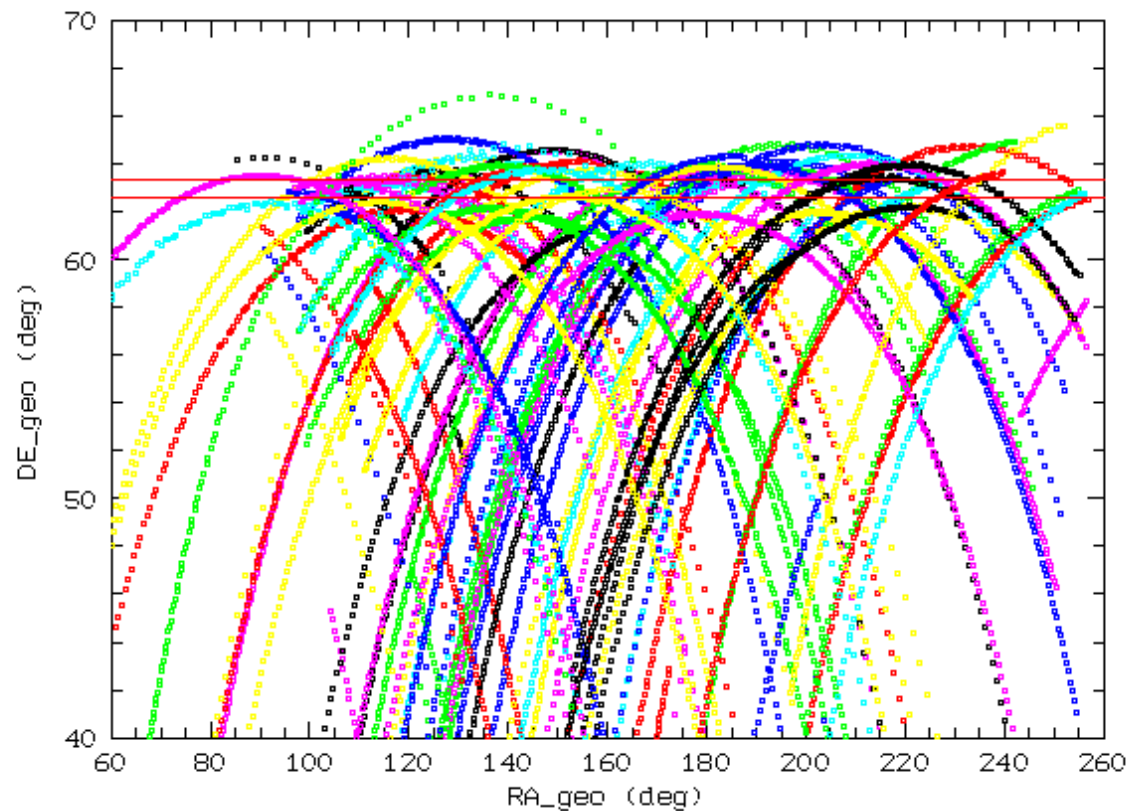
- Phase angles (topocentric, OGS)

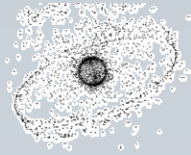




MEO Observation Strategies

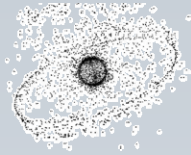
- Where to look?
 - Geocentric passes; OGS, one night



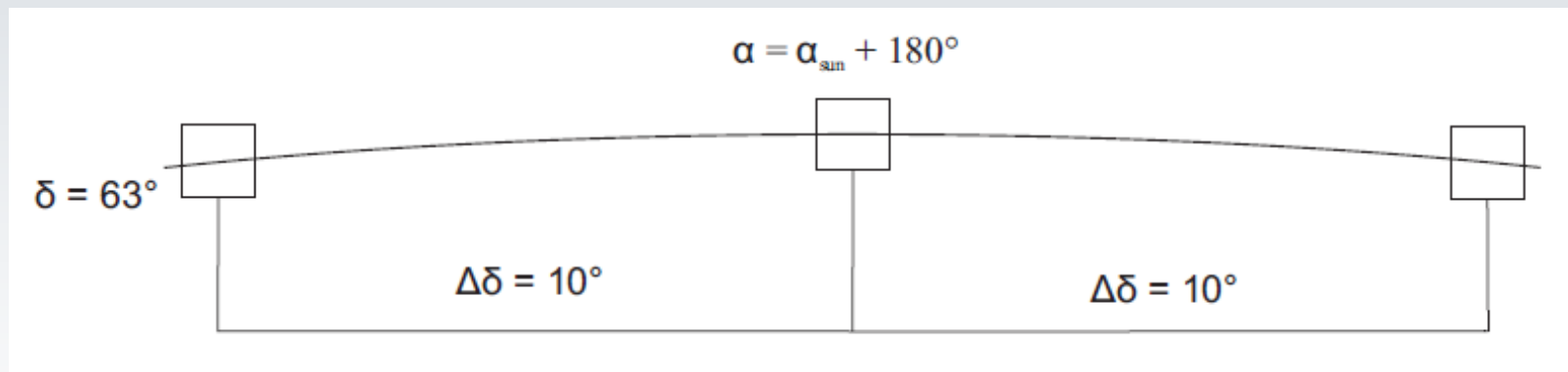


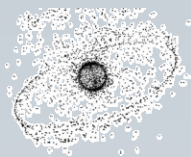
Observations

- First observations in December 2012 at OGS, 1-m Zeiss telescope, 0.7x0.7 square degrees
- Survey fields in anti-sun direction (right ascension)
- First test field
 - all known TLE objects were found
 - no uncorrelated objects found
- Survey and follow-up observations were performed
 - In January 3 successful nights of observations
 - In February 3 successful nights of observations
 - In April 3 successful nights of observations
 - In July 3 successful nights of observations
 - In August 1 night
- Follow-up observations performed with ZIMLAT



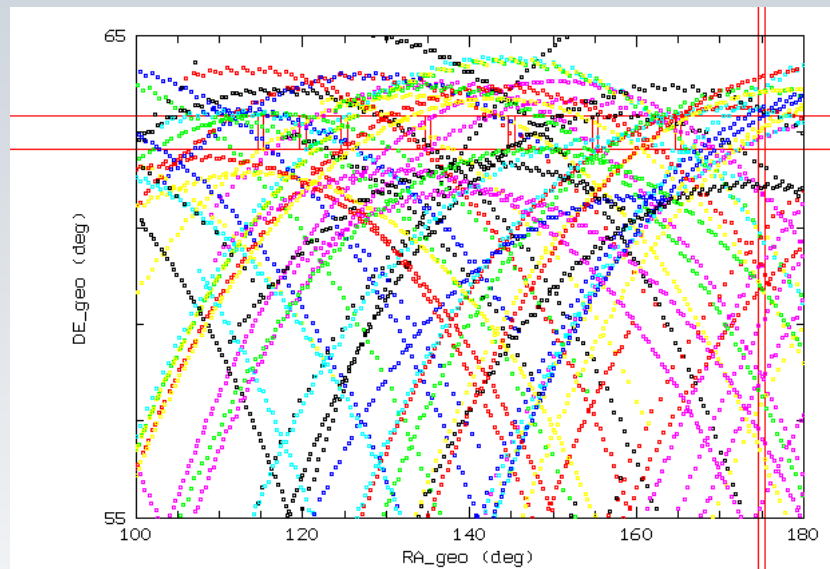
- Survey strategy with 3 fields per month displaced by 10° in right ascension

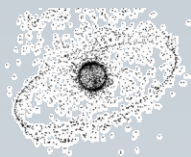




Survey Fields

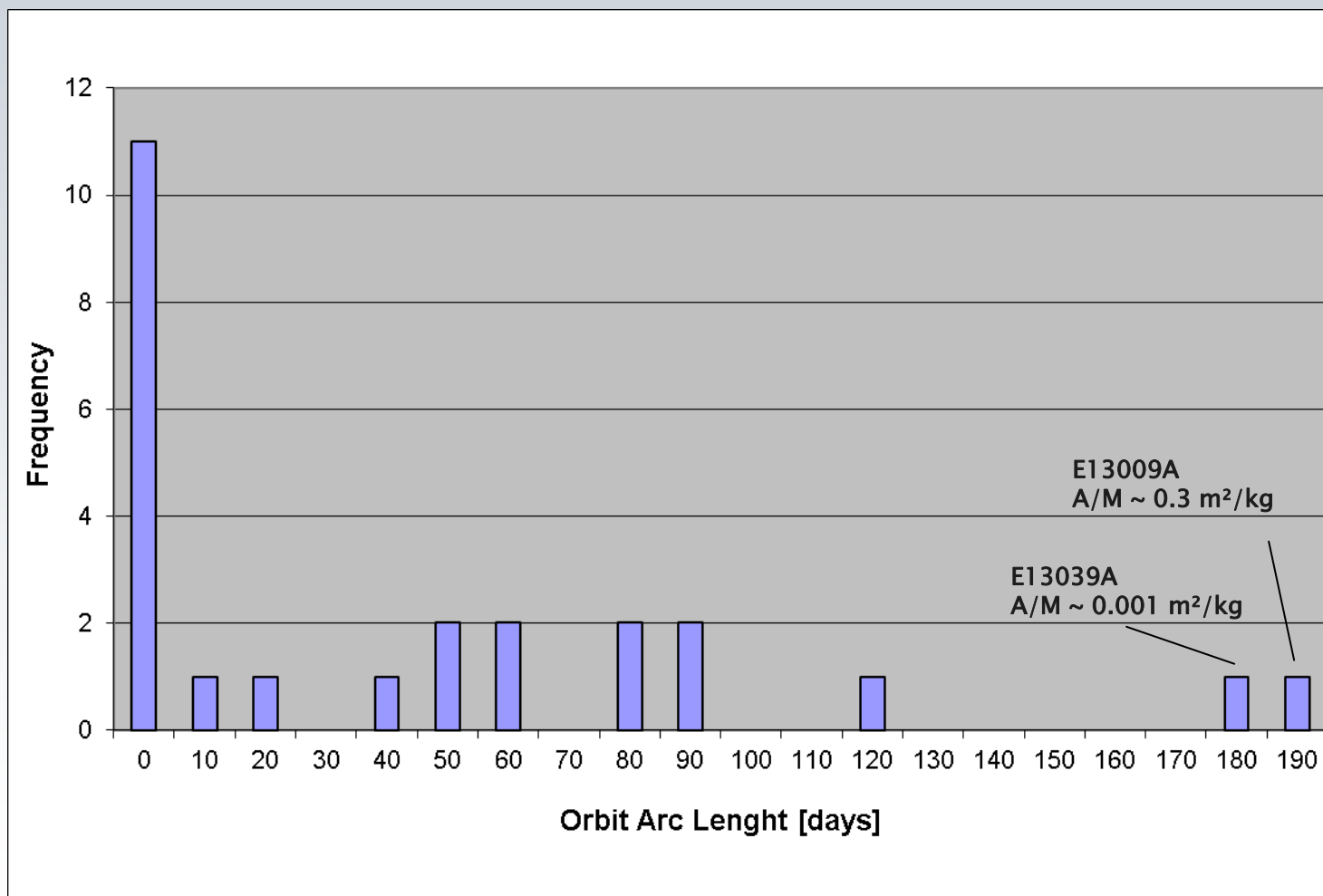
- 13 nights \rightarrow 13 fields
- $\Delta RA = 10\text{deg}$
- Each survey = 11 min
- 11–42 surveys/night
- 257 surveys ($\sim 47.1\text{h}$)
- 30 uncorr. objects found (~ 0.6 objects/hour)
- Follow-up observations of 25 objects performed
- 5 objects still „active“



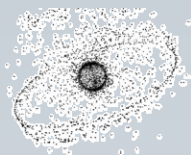


Uncorrelated Molniya

Molniya objects (Jan 2013 – Aug 2013)

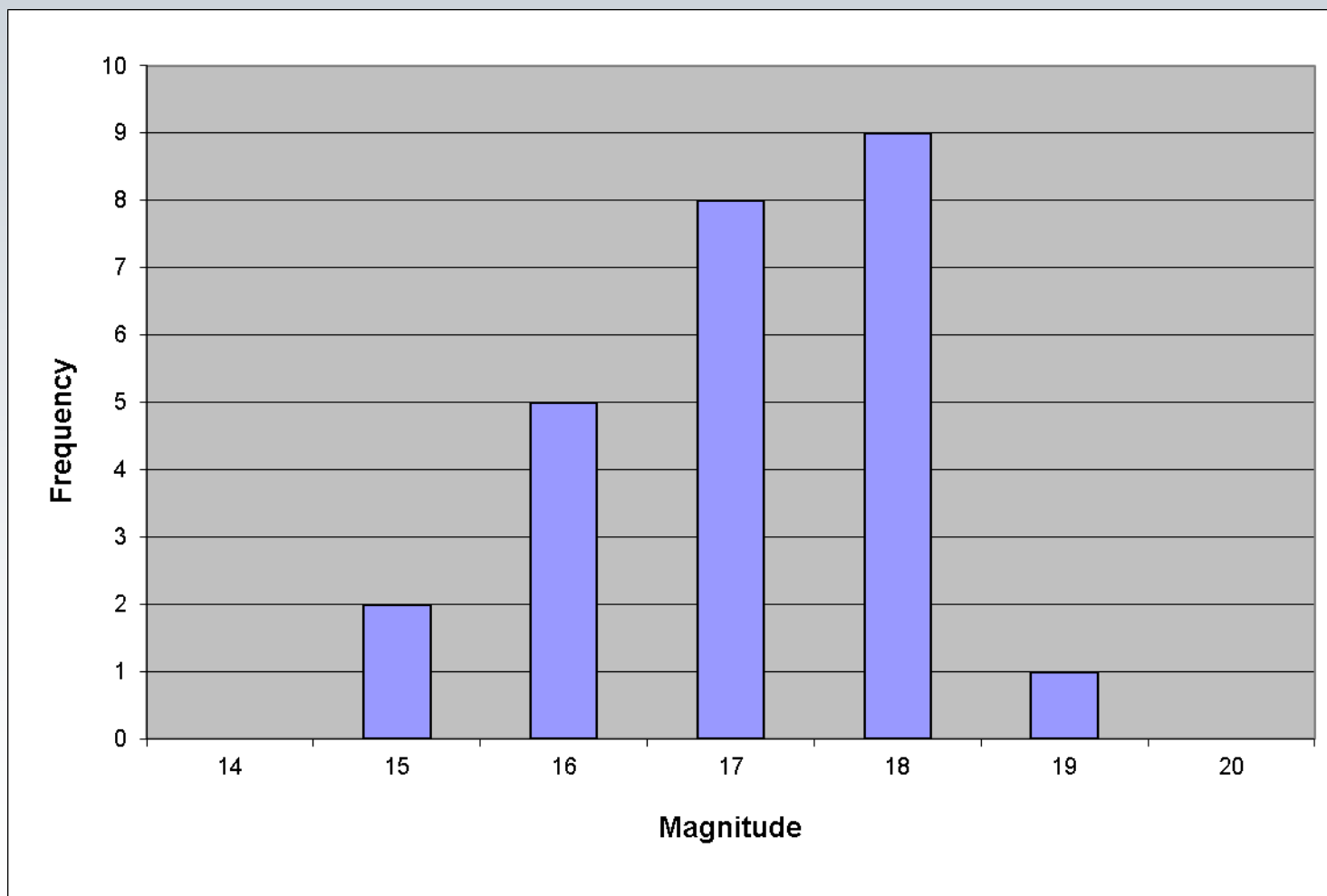


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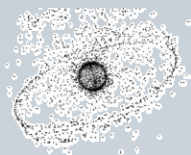


Uncorrelated Molniya

Molniya objects (Jan 2013 – Aug 2013)

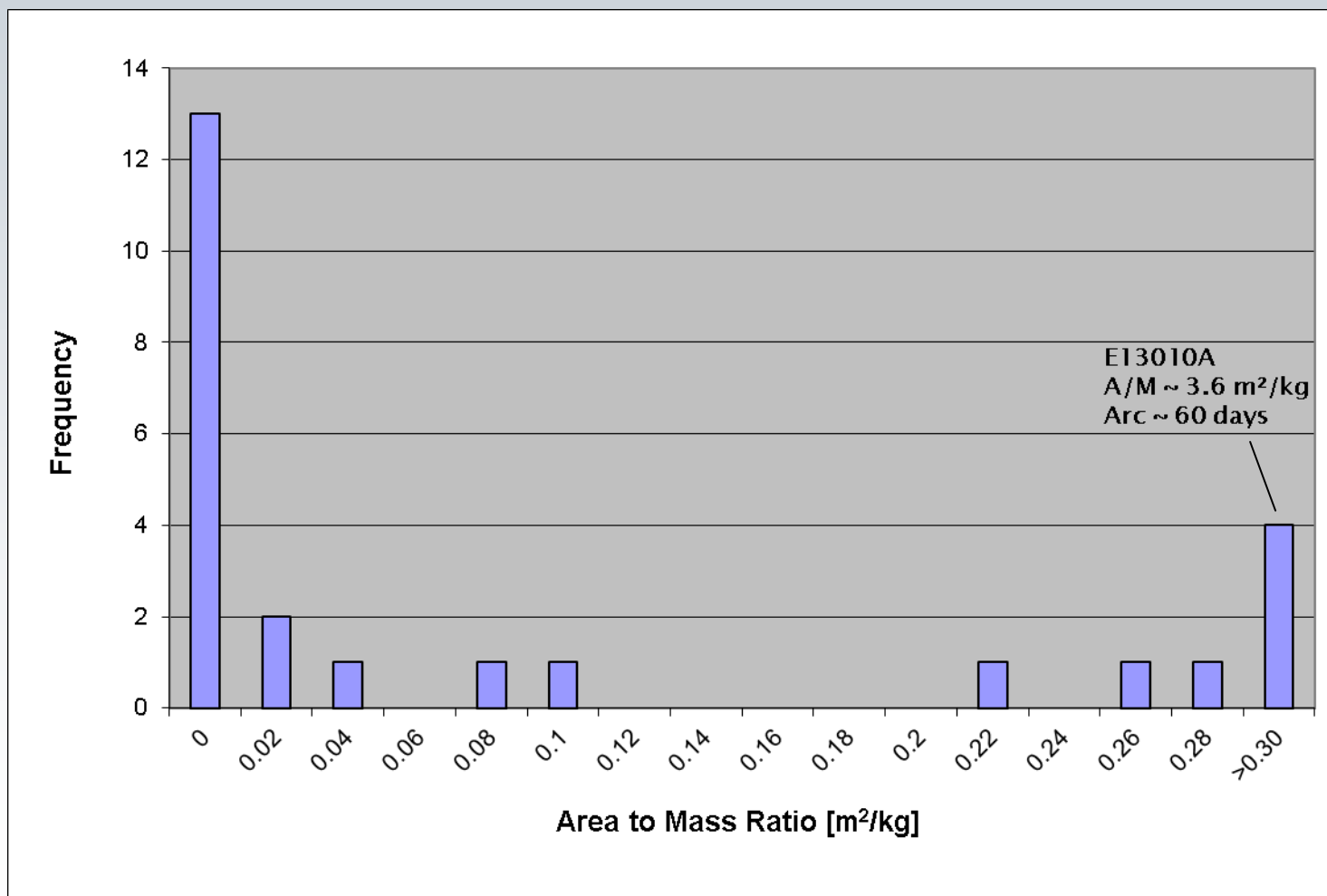


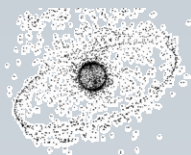
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Uncorrelated Molniya

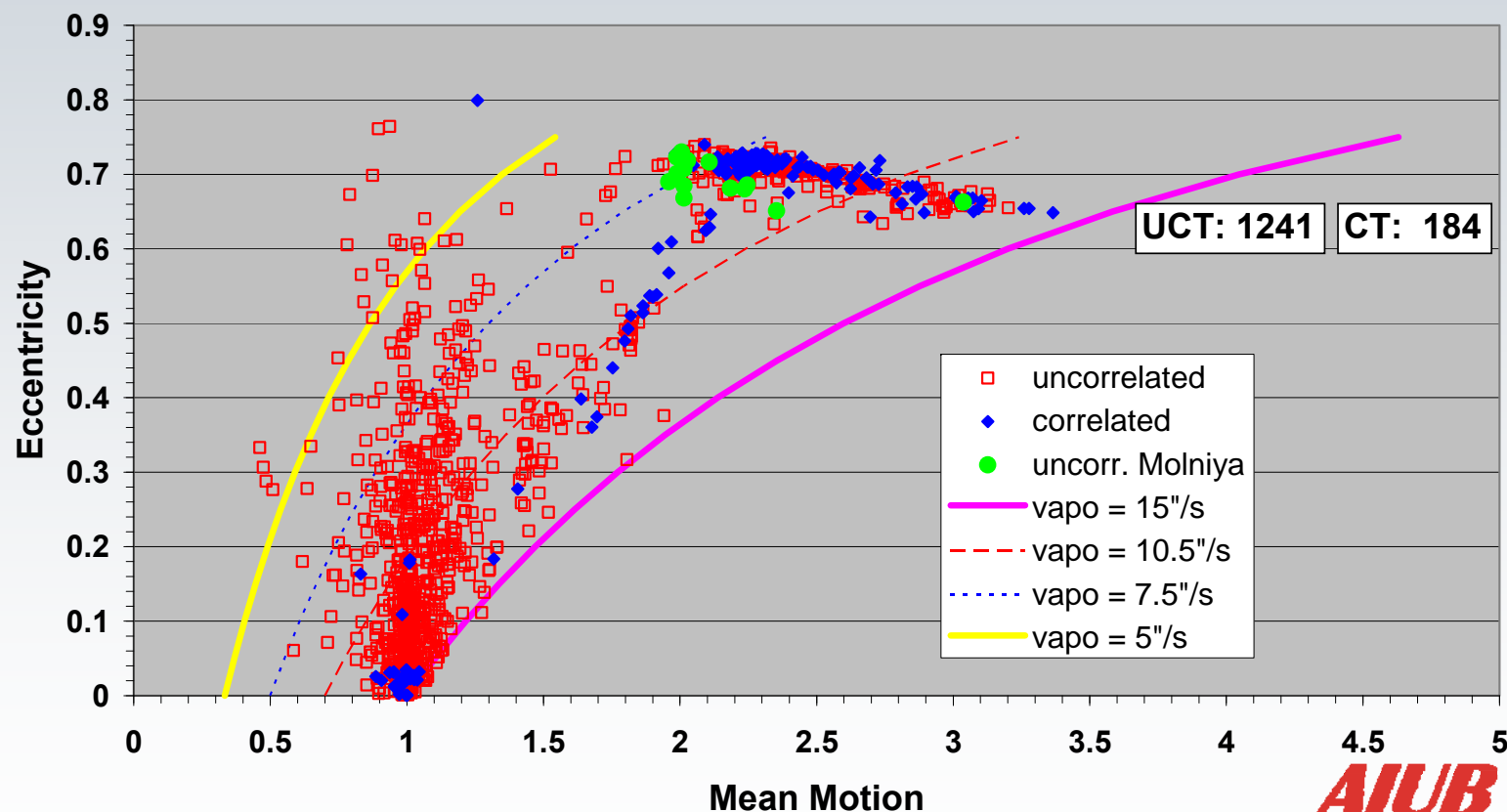
Molniya objects (Jan 2013 – Aug 2013)



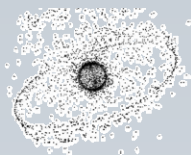


Uncorrelated Molniya

Eccentricity vs Mean Motion (Jan 2002 - Mar 2013; elliptical orbits)

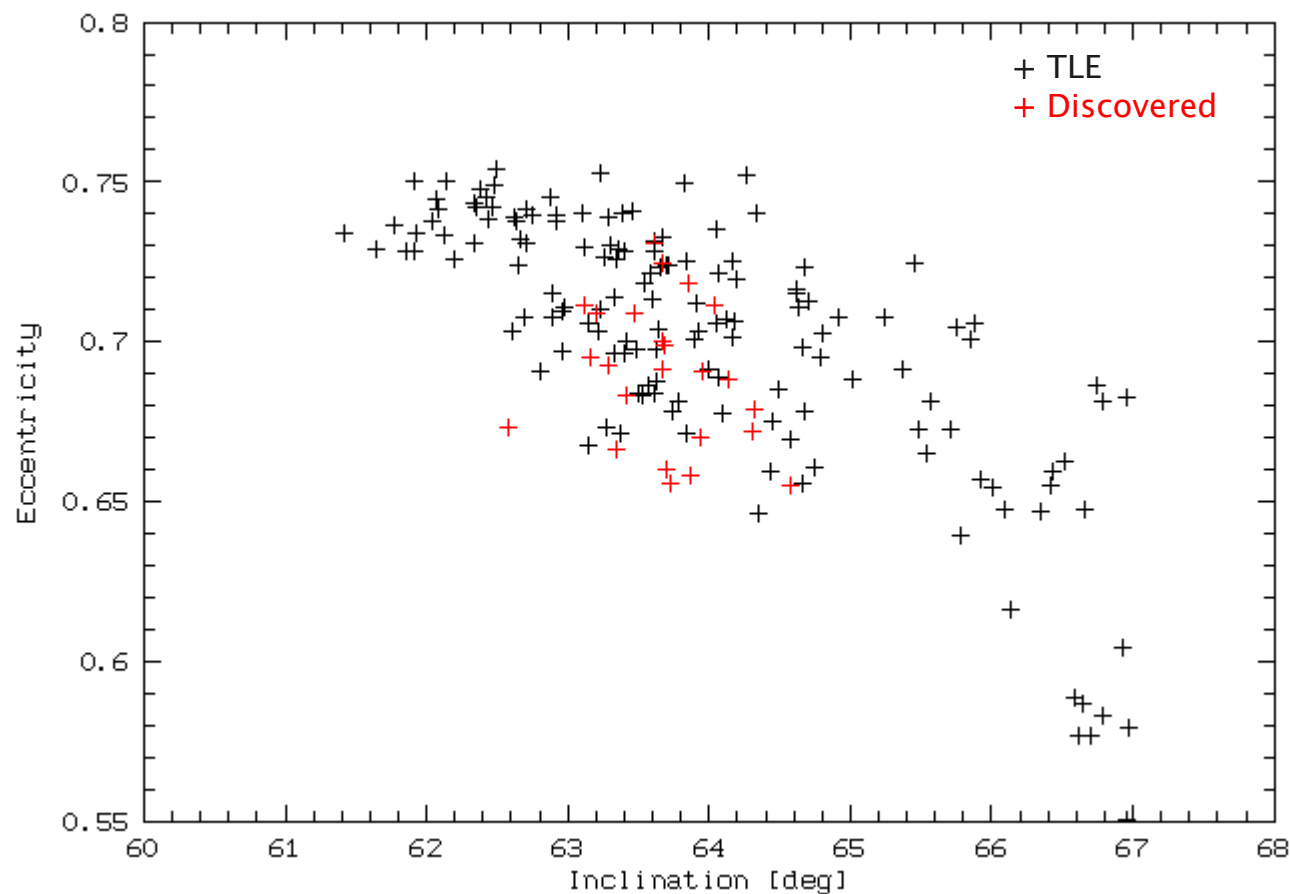


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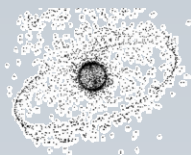


e vs i

Molniya objects (Jan 2013 – Aug 2013)

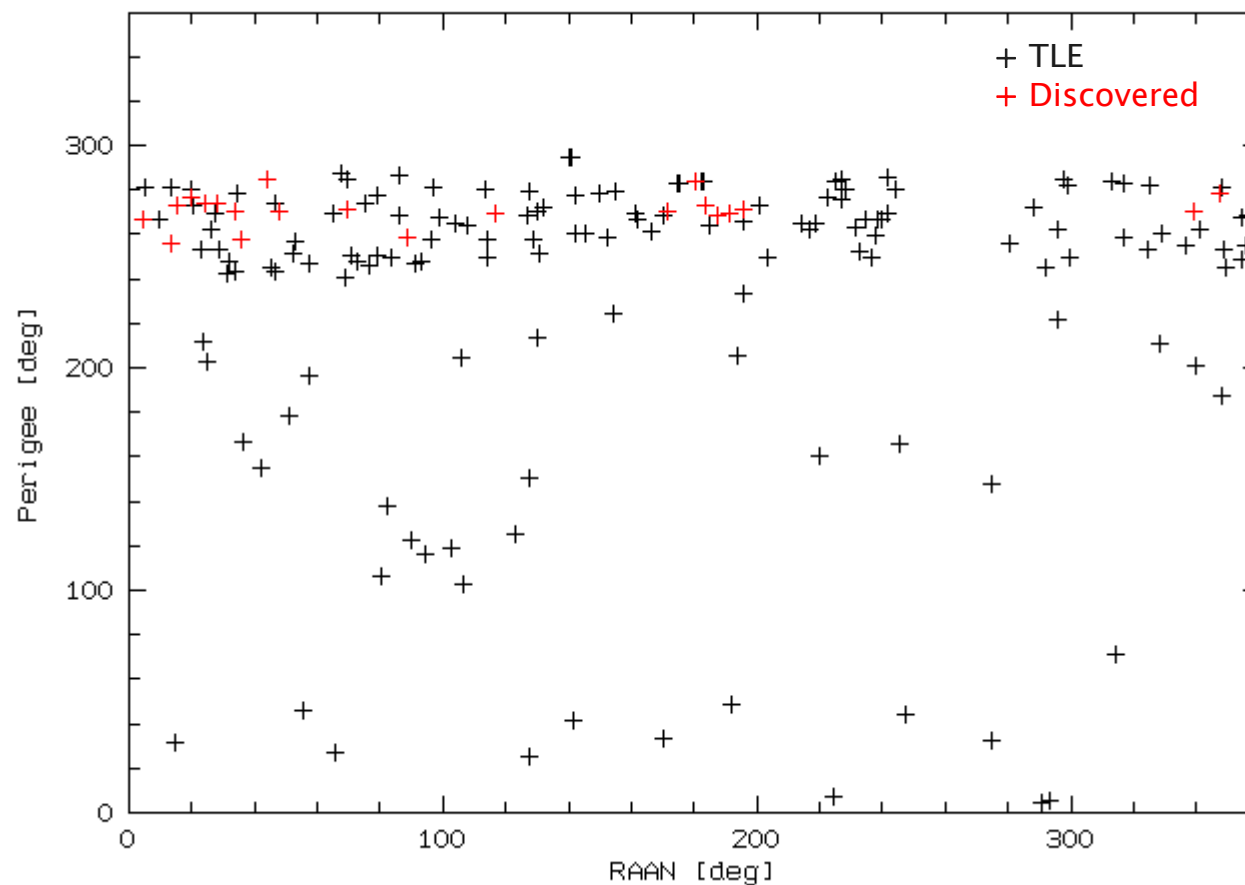


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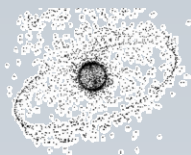


Perigee vs Node

Molniya objects (Jan 2013 – Aug 2013)

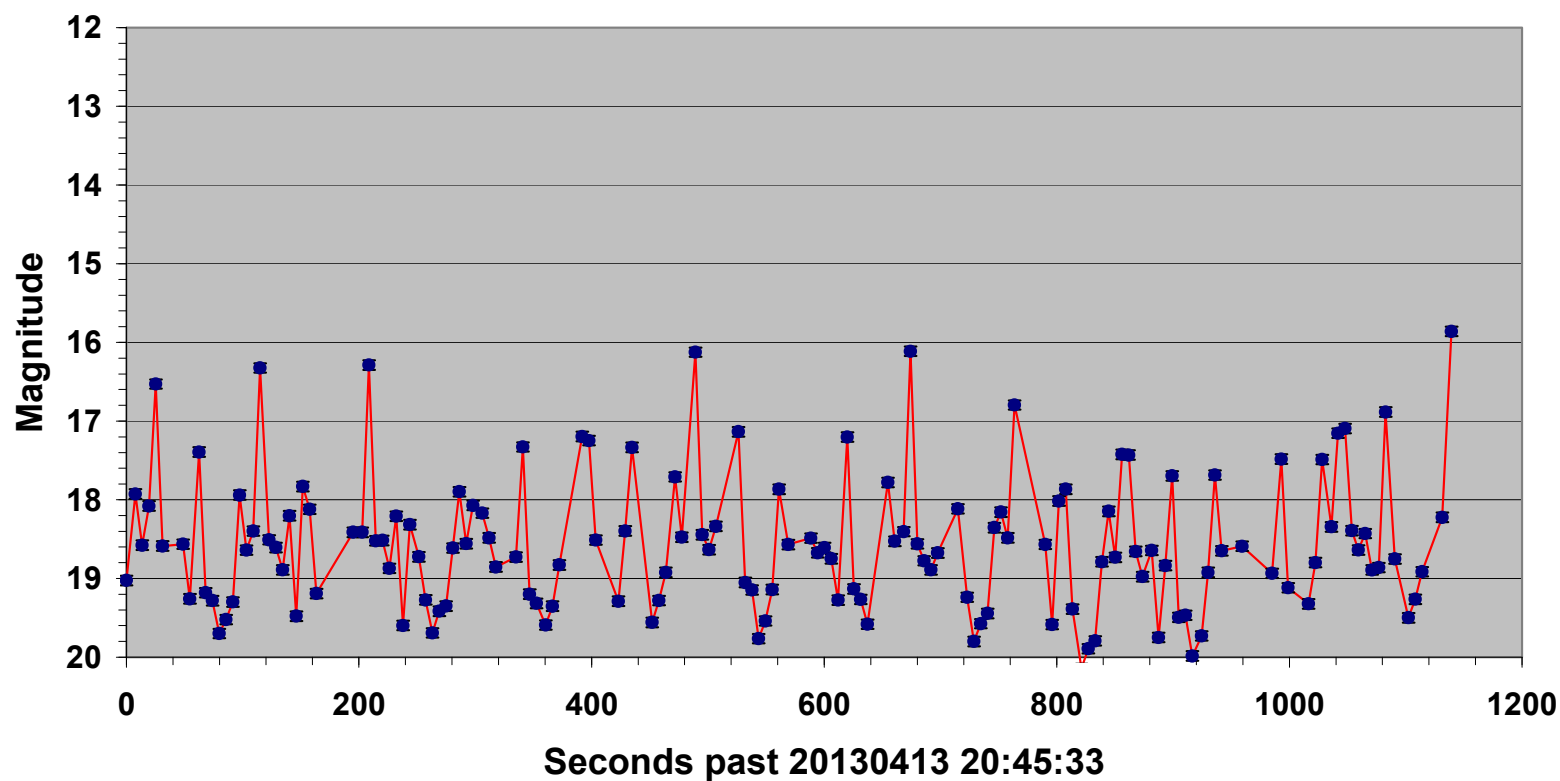


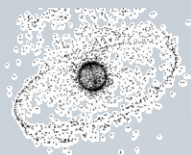
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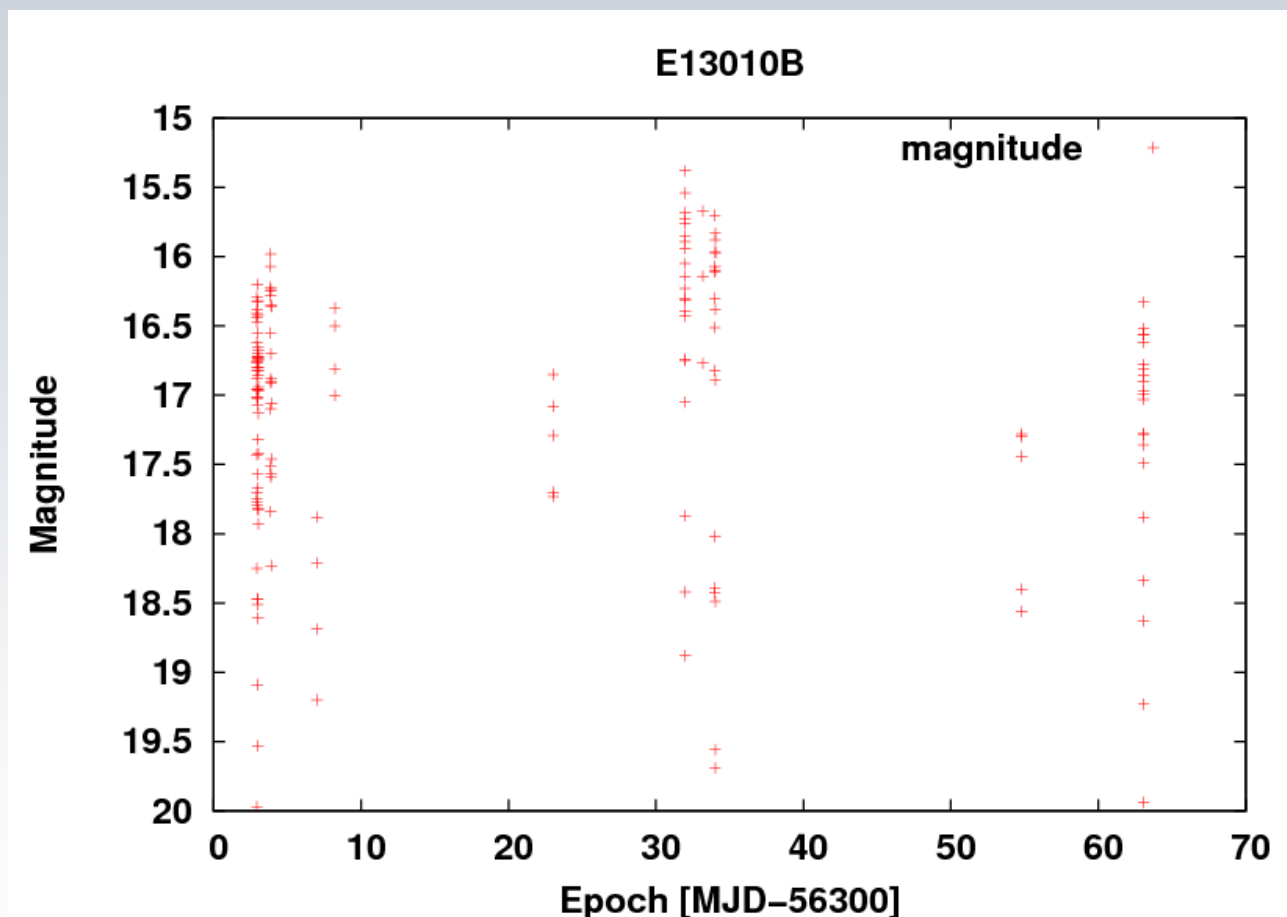
Brightness Variation

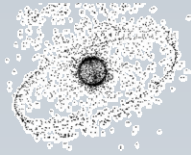
Light Curve 13039A





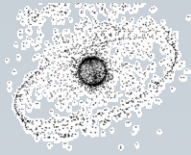
Brightness variation





Conclusions

- Efficient observation scenarios for eccentric MEO orbits (particularly Molniya) were developed and their performance assessed
- Test observations (13 nights)
30 uncorrelated objects found (~0.6 objects/hour)
- Objects highly variable in brightness
→ light curves acquired
- High percentage of higher A/M objects, also HAMR objects
- Objects often too faint to follow up with ZIMLAT, only 5 objects still in catalogue
- Observation campaign is ongoing...



Future work

- Statistical evaluation to follow (feedback to models)
- Comparison with models by using ESA PROOF-2009 program
- ESA MASTER statistical population comparison with real observations
- The “shows” and “no-shows” analysis with TLE population